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Aluminum Alloy 7068 Mechanical Characterization

by Michael Minnicino, David Gray, and Paul Moy

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A relatively new alloy of aluminum is being marketed as “ordnance aluminum” by its developer, Kaiser Aluminum (Foothill Ranch, CA), owing its history to the development of ordnance applications. The aluminum alloy designation, 7068, is the strongest aluminum commercially produced. This alloy is aluminum zinc, with an advertised minimum yield strength of 99 ksi. This report characterizes extruded 7068 aluminum in terms of its elastic properties and mechanical strength, in sizes of interest to large-caliber munition designers.				
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1. Introduction

A relatively new alloy of aluminum is being marketed as “ordnance aluminum” by its developer, Kasier Aluminum (Foothill Ranch, CA), owing its history to the development of ordnance applications in the mid 1990s (1). The aluminum alloy designation, 7068, is the strongest aluminum commercially produced. This alloy has an advertised minimum yield strength of 99 ksi (2). The commonly specified material properties for extruded 7068 aluminum are shown in table 1, along with 7050 and 7075 aluminum alloys for comparison (3).

Table 1. Mechanical property comparison of high-strength aluminum alloys.

Property	Alloy		
	7068	7075	7050
Elastic modulus (Msi)	NA	10.4	10.3
YTS (ksi)	94	73	70
UTS (ksi)	103	83	81
Elongation (%)	5	11	10

Note: NA = not available.

It is assumed in the listing of these properties that they are isotropic. However, the extrusion of the metal stock results in preferential orientation and elongation of the crystals, resulting in deformation-induced anisotropy. The result of this anisotropy is the directional dependence of material properties, especially strength. The elastic modulus that defines the slope of the linearly proportional part of the stress-strain curve is insignificantly affected by deformation-induced anisotropy. Another important and often overlooked assumption is that these properties are invariant with respect to the size of extruded stock. The objective of this work is to characterize extruded 7068 aluminum in terms of its elastic properties and mechanical strength in sizes of interest to large-caliber munition designers.

2. Tension Tests

The 7068 aluminum alloy is relevant for large-caliber projectile applications. As a result, test specimens were electronic discharge machined in accordance with ASTM E8 (4) from a 6-in-diameter billet in both the billet’s extruded (i.e., longitudinal) and transverse directions. The specimen geometry is shown in figure 1. The specimens were painted with a speckle pattern for strain measurement purposes using digital image correlation (5), clamped in an Instron 1127, and pulled at a rate of 0.1 in/s.

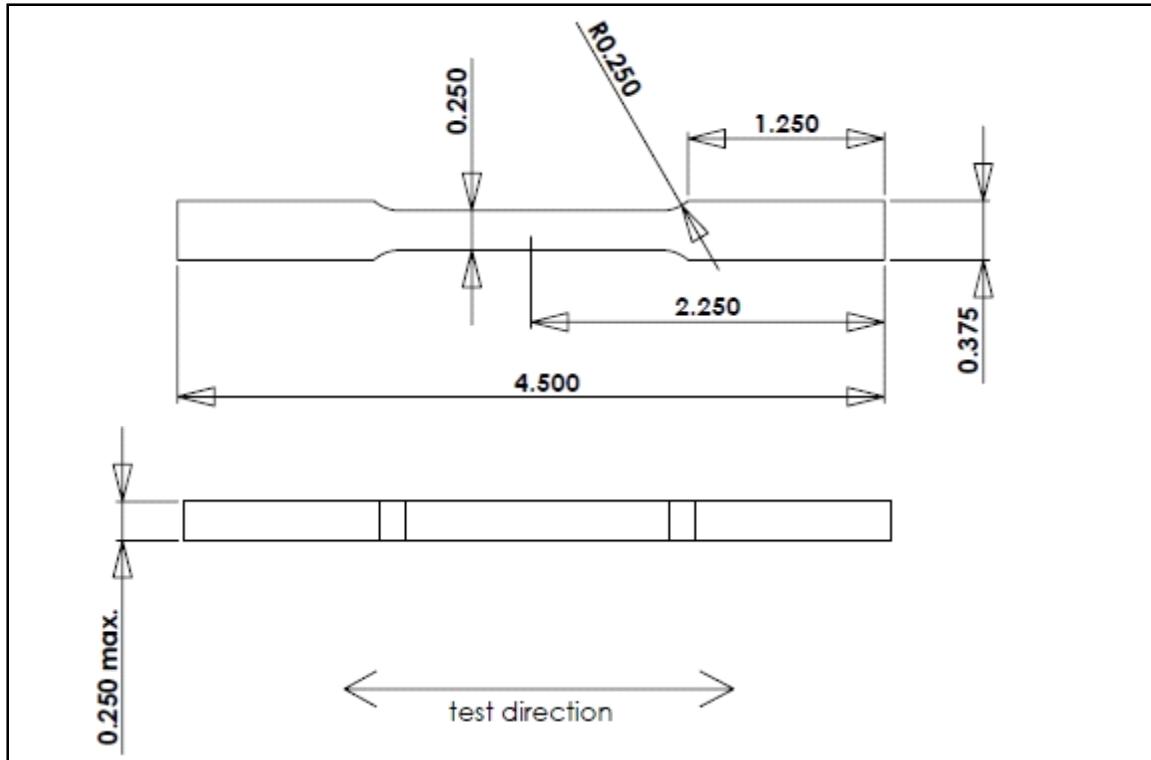


Figure 1. Tension test specimen geometry (units are in inches).

3. Results

The mechanical properties computed from the longitudinal and transverse tension test data are shown in tables 2 and 3, respectively. The elastic modulus is calculated using a linear least-squares regression from the linear portion of the stress-strain curve. As expected, the calculated elastic moduli for the longitudinal and transverse directions differ little from each other. The yield tensile strength (YTS) is taken as the stress at 0.2% strain. The ultimate tensile strength (UTS) is the maximum stress seen during the tensile test. The elongation is taken as the largest strain value before specimen rupture (failure). As expected, the longitudinal direction (i.e., the aluminum billet's extruded direction) has a larger YTS and UTS compared to the transverse direction. These findings agree with the larger longitudinal yield and UTS values reported by Advanced Materials International (AMI) (1).

The directional-dependent mechanical properties of AMI are shown in table 4. The directional dependence is attributed to the preferential crystal orientation resulting from the extrusion manufacturing process where the crystals become aligned and elongated along the extrusion direction. The nonrandom distribution of crystal orientation affects the macroscopic mechanical properties, particularly strength values (6). The current experimental results compare well with

Table 2. Experimental longitudinal direction properties.

Material Property	Longitudinal Direction					
	Test 1	Test 2	Test 3	Test 4	Average	Std. Dev.
Elastic modulus, E (Msi)	10.98	10.05	10.15	10.13	10.33	0.438
Yield strength (ksi)	92.8	91	96.1	96.7	94.20	0.003
UTS (ksi)	98.9	97	101.2	102.1	99.80	2.30
Elongation (%)	10.4	11.5	11.9	15.2	12.25	2.07

Table 3. Experimental transverse direction properties.

Material Property	Transverse Direction				
	Test 1	Test 2	Test 3	Average	Std. Dev.
Elastic modulus, E (Msi)	10.04	9.94	9.97	9.98	0.051
Yield strength (ksi)	75.5	75.4	74.5	75.13	0.001
UTS (ksi)	82.2	82.3	82.3	82.27	0.06
Elongation (%)	2.7	3.1	3.4	3.07	0.35

Table 4. Typical mechanical properties per AMI.

Direction	YTS (ksi)	UTS (ksi)	Elongation (%)
Longitudinal	99.1	102.9	9
Transverse	87.5	93.5	7

Kaiser's specified minimum values for the longitudinal direction. The current results indicate that reductions in strengths and elongation are significant. The stress-strain curves for the longitudinal and transverse direction specimens are shown in figures 2 and 3, respectively.

4. Discussion

The longitudinal tensile specimens displayed ductile failure surfaces that are inclined 45° relative to the load direction. Conversely, the transverse specimens exhibited a more brittle-like failure surface that was roughly perpendicular to the load direction. This behavior is evident from observation of the stress-strain curves shown in figures 2 and 3. The strain to failure for the longitudinal specimens is greater than 10%, whereas the average strain to failure for the transverse specimens is less than 3.5%. Additionally, the YTS and UTS for the transverse direction are lower than the longitudinal direction. AMI notes this directional strength behavior as well. The calculated elastic moduli for the longitudinal and transverse directions differ little and compare well to the published data. The current experimental computed material properties compare well with the published data, except for elongation. A summary of the 7068 extrusion direction properties is shown in table 5.

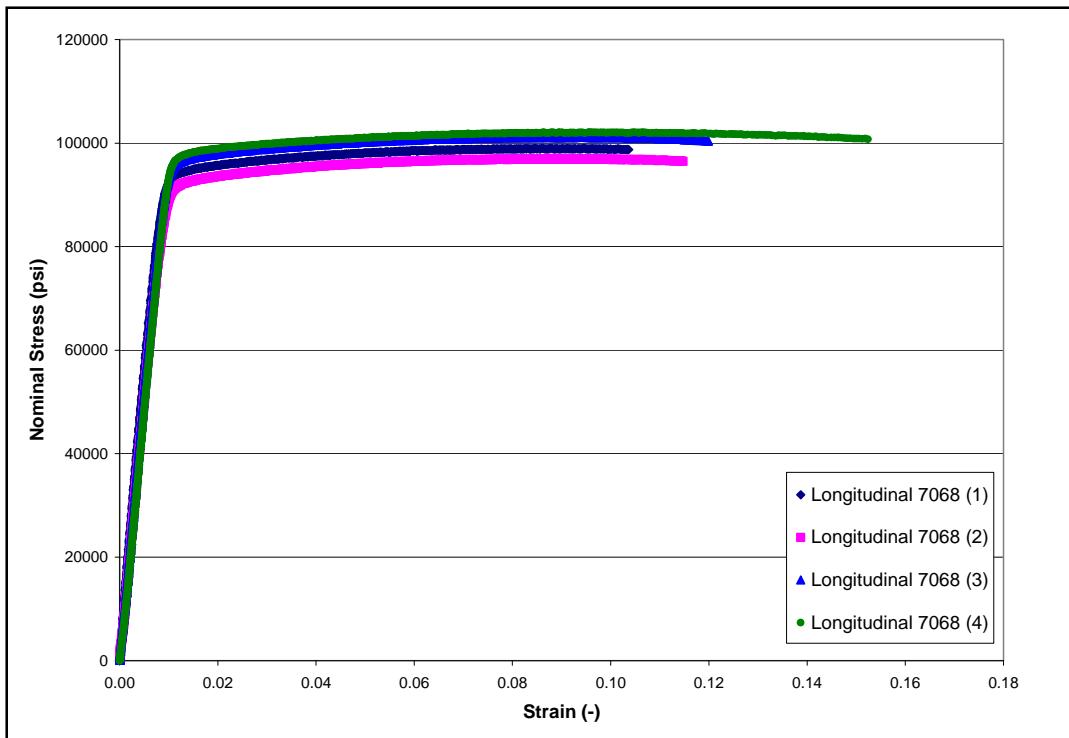


Figure 2. Longitudinal direction stress-strain curves.

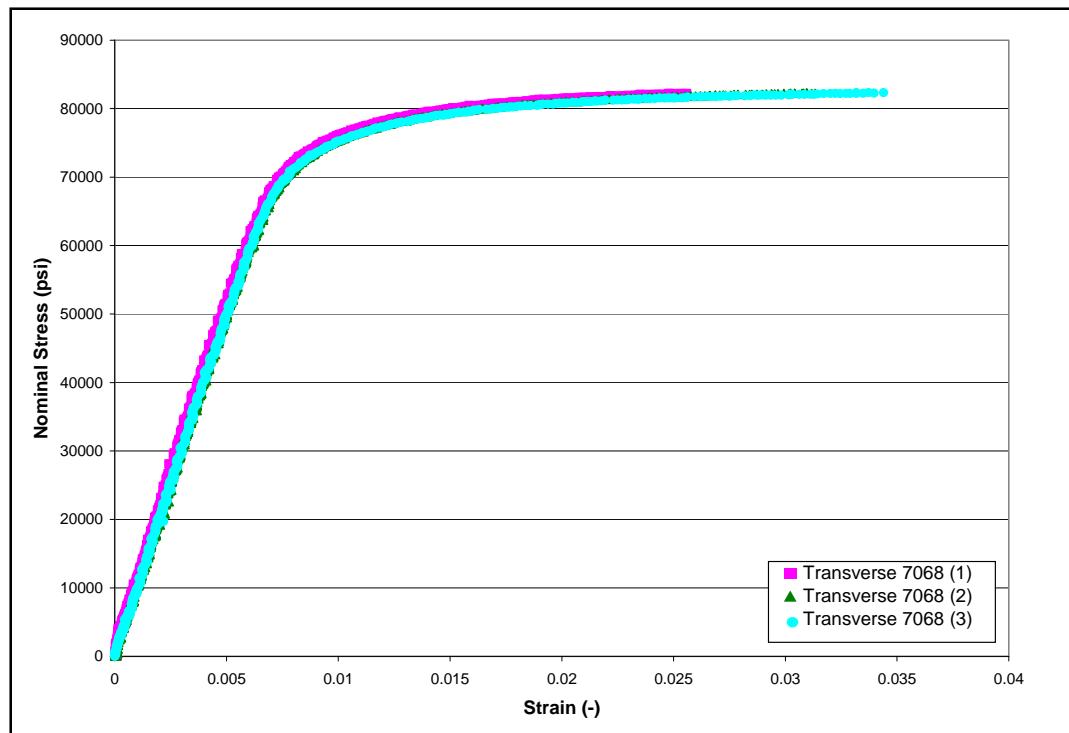


Figure 3. Transverse direction stress-strain curves.

Table 5. Summary of 7068 aluminum extrusion direction strengths.

Organization	Section (in)	YTS (ksi)	UTS (ksi)	Elongation (%)
AMI	3–6.5 in	90	94	5
Kaiser	Unknown	99	103	9
ARL data	6 in	94.2	98.8	12.25

Note: ARL = U.S. Army Research Laboratory.

5. Summary

To date, 7068 aluminum alloy is the strongest commercially-produced aluminum. Strengths for large-caliber, munition-sized components are experimentally found to have a minimum YTS of 91 ksi and minimum UTS of 97 ksi, with a minimum strain to failure of 10.4% in the longitudinal (i.e., extruded) direction. The transverse direction properties are less due to the preferred crystal orientation. The transverse direction strengths have a minimum YTS of 74.5 ksi and a minimum UTS of 82.2 ksi, with a minimum strain to failure of 2.7%. These numbers compare well with other published data.

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